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Research article

The politics of next generation research: democratizing research-centred computational networks

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Abstract
Research on information technology has been focused primarily on the worlds of IT and management systems for business and government to the relative neglect of research on the digital and institutional infrastructures that underpin the research enterprise itself. When digital research is studied, the emphasis has been on the diffusion of technological innovations, rather than the social and political dynamics shaping the design and role of technologies in research. However, what researchers know, and with whom they collaborate, could be transformed through the strategic use of advances designed to support research, defined here as 'research-centred computational networks'. This article presents a framework for conceptualizing the social and technological choices shaping the next generation of research in ways that could open – democratize – key aspects of the research process that move well beyond academic publication. The framework highlights the limited scope of innovation to date, and identifies a variety of factors that maintain and enhance institutional control over the research process, at the risk of losing the creative and productive bottom-up participation by networked researchers and citizen researchers among the public at large. Conceptualizing, prioritizing and advancing study of next generation research is one of the most significant but difficult challenges facing scholars of information technology.

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Introduction

It took four decades after the invention of the Internet before there was widespread recognition that this rapidly evolving 'network of networks' was fundamentally transforming how people get information, communicate with others, obtain services and interact with information technologies. It has reconfigured not only how people get information – in all these respects – but also the outcomes of these activities, reshaping what we know, who we know, what services we obtain and what information technologies we use. In all these ways, an array of actors have used the Internet to 'reconfigure access' to information in everyday life and work (Dutton, 1999, 2005).

The Internet evolved from ARPANet, developed to support research through the sharing of computational resources among computer scientists. Since that time, the development of e-mail and the use of attachments and file transfer protocols have enabled the Internet to play an increasingly important role in research across all disciplines of the sciences and humanities. However, in the first decade of the 21st century, technological innovations in Grid and Cloud computing, for example, have fostered visions of a new generation of information technologies tied to step jumps in the networking and computational capacity available to researchers. These have led to a wide range of initiatives aimed at using advanced technologies for applications in support of research through collaboratories, e-Science, e-Social Science, computational social science, e-Humanities, e-Research and 'digital scholarship' – some of the many labels assigned to this new wave of initiatives around digital research (Borgman, 2007; Dutton and Jeffreys, 2010).

Social research on information technologies aimed at supporting research is rare, and what research that is done has largely focused on the development and demonstration of new tools, such as ‘collaboratories’ (NRC, 1993; Finholt and Olson, 1997), and their diffusion across the sciences and humanities (Dormans, 2009). The primary critiques have focused on the failure of researchers to take up many of these tools, and the limited impact of their use, leaving many to dismiss the potential of digitally enabled scholarship as more technological hype than social reality (Nentwich, 2003).

This article describes the technological and social innovations behind this next generation of research technologies, what I will call ‘research-centred computational networks’ (RCNs), and then presents a framework for studying the choices shaping their use and impact on the quality of, and access to, research. This framework is used to explain the potential significance and transformative nature of these innovations, despite limits on their use to date. It is important to move beyond a focus on the diffusion of these innovations in the past few years, given the many constraints on institutional change in academia, and focus on their implications for opening, even democratizing, research over the coming decades by better enabling researchers to ‘innovate for themselves’ (von Heppel, 2005: 1). The contours of this transformation are already evident in a few leading-edge research initiatives as well as developments outside the research community.

Approach: synthesis of case studies and leading projects

The framework presented here emerged through efforts to synthesize the findings of research on a large, multidisciplinary Oxford e-Social Science (OeSS) project, which focused on understanding the social shaping and implications of e-Research, primarily in the UK.[1] This was part of a larger programme of research that sought to give the UK research community a lead in advancing understanding of how to progress applications and other e-infrastructure initiatives for the social sciences. However, the OeSS team sought to apply the social sciences to identify and explore the factors shaping the development of information technologies across the sciences and humanities, more generally, and their implications for research.

The project brought together a multidisciplinary team, and used a variety of techniques to analyse a series of case and issue-based studies of digitally enabled research. This article provides one synthesis of these cases and issue-based studies, augmented by leading projects around the world that illustrate the challenges and potential for a next generation of research.

The OeSS cases were purposively selected to ensure variation across our studies on such aspects as types of data (such as data on people *vs* objects), and tools (such as for modelling and simulation *vs* distributed annotations of qualitative data *vs* collaboration). Different issues arise around particular data and tools. Issues are linked also to the research context, such as their disciplinary base, around qualitative and quantitative research styles and the extent to which they are oriented towards basic or applied research. Table 1 provides a brief overview of cases by type of data and tools, with selected studies being brought into this article to illustrate key points.[2]

In addition to these case studies, the OeSS project conducted a set of issue-based studies throughout the duration of the project. The key foci of the issue-based studies included ownership, particularly in relation to institutional infrastructures, including copyright, Intellectual Property Rights (IPR), liability, and contracts; open science; the ethics of network enabled research; privacy and data protection, including issues of anonymity and confidentiality, and the definition of personal data; and the diffusion and sustainability of digital tools and infrastructures for scholarly research. These were based on continuing reviews of literature, in-depth interviews, uniquely tailored studies, specialized surveys, the OeSS case studies and insights gained from particularly innovative projects, such as Galaxy Zoo.

This article focuses on four general themes that emerged from this synthesis of the case- and issue-based studies:

1. The digital technologies and applications that underpin the next generation of research, leading me to the concept of RCNs.
2. How the design and application of advanced Internet and Grid technologies for research is likely to reconfigure access, highlighting the potential for empowering networked researchers *vs* institutions.
3. The ecology of social and technological choices made by a wide array of researchers and other actors shaping the design and use of e-Research.
4. Factors that shape and constrain this ecology of choices, which define the politics of next generation research over the coming decades.

Research-centred computational networks

Advanced Internet and Web developments were a basis for early public funding of collaboratories (NRC, 1993), and later innovations, such as around Grid computing, spurred initiatives around cyberinfrastructure, in the US, and e-Science and e-infrastructure programmes in the UK (Atkins, 2005; Dutton and Jeffreys, 2010). Cross-nationally and overtime, the nomenclature has changed, but has encompassed a wide spectrum of sophisticated information and communication technology (ICT) capabilities, typically involving the use of large-scale data sets and support for distributed collaborations that leverage access to powerful computational capabilities and collaborative environments for undertaking research.

A key example of an innovation in computation and networking that was thought to be a driver of new forms of research was the Grid (Berman *et al*., 2003; Jeffreys, 2010). Grid computing software enables many computers, in the same or distributed locations, to work together as if they were a more powerful single system. The term Grid was coined by pioneers of this technique (Foster and Kesselman, 1999) to indicate their vision of providing a computing utility equivalent to an electricity grid, into which users could ‘plug’ their own systems. This predated more contemporary conceptions of ‘cloud’ computing, which are built on similar conceptions of shared computing services and could also provide distributed computational

Table 1 OeSS studies of e-research projects, data and tools

Case study	*Embedded projects*
Qualitative data	Qualitative Digital Records (DReSS) Mixed Media Grid (MiMeG), collaborative annotation and analysis of video data on interpersonal communication Qualitative data at the UK Data Archive's Economic and Social Data Service (Qualidata) OpenNet Initiative, using fusion methodology to remotely collect data globally on Internet content filtering
Quantitative data	Virtual Safe Settings, including a Virtual Microdata Laboratory Swedish Initiative for Micro-data in the Social and Medical Sciences (SIMSAM)
Biological and bio-medical	Diagnostic Mammography National Database Project (eDiaMoND), pooling and distributing digital images Integrative Biology Virtual Research Environment (IBVRE) Genetic Association Information Network (GAIN) Swiss Bio Grid, national initiative to create a research-centred computational network for the sciences Marine Mammal Digital Photography, the move to digital by marine mammal researchers and its consequences
Collaborative virtual research environments	Access Grid, multipoint computer-based videoconferencing application integrating audio, video and textual tools, such as chat, for virtual meetings Joint Information Systems Committee (JISC) Funded VRE Projects, including IBVRE CombeChem, test-bed for synthesis of new chemical compounds through combinatorial methods Obesity e-Lab, secure environment for sharing among epidemiologists, public health workers and social scientists
Web 2.0 collaborative environments	MyExperiment, a VRE designed to pool and share scientific workflows and data *Journal of Visualized Experiments* (*JoVE*) OpenWetWare, a Wiki to support sharing of information in biology and biological engineering Pynchon Literary Wiki (Wiki on works of Thomas Pynchon)
Simulation-visualization	Heart Modelling by the Oxford Cardiac Electrophysiology Group, along with other simulations within Systems Biology Geographic Virtual Urban Environments (GeoVUE) Modeling and Simulation for e-Social Science (MoSeS)

resources of much value to supporting research (Hey *et al*., 2010).

For a short period of time, efforts to develop next generation research, particularly in the UK, were focused almost exclusively on Grid computing. However, since 2004, restrictive definitions were relaxed as no single technological vision dominated, and a wide range of networked computational resources proved useful to new forms of collaboration and computation. For example, some approaches to crowd sourcing have been of value to science, but also in business and civil society, and these applications could employ more state of the practice applications of the Internet, such as e-mail and the Web (Dutton, 2008). The common denominators are that they are focused on supporting research through advances in networking and computational approaches, often in combination. For that reason, I developed the term 'Research-centred Computational Networks' (RCNs) to encompass the range of network and digital technologies supporting research – providing a concept that is not tied to a national initiative or academic discipline (Dutton and Jeffreys, 2010: 6–7).

An early Grid computing project illustrates how such technological innovations could generate visions of a new era of RCNs. Called the 'Screensaver Project', faculty of the Chemistry Department at Oxford University, with support from the National Foundation for Cancer Research and a variety of sponsors from the computing industry, built a database of molecules that were to be virtually screened to determine if they had the potential to counteract cancer or inhibit other diseases, such as smallpox (Richards, 2002). A critical technological feature of this project was the use of Grid computing software to exploit the spare capacity of screensavers on over 3.5 million personal computers distributed over 200 nations in order to provide the computational power for this screening. Owners of personal computers around the world were asked to participate. The project Web site noted:

> Anyone, anywhere with access to a personal computer, could help find a cure for cancer by giving 'screensaver time' from their computers to the world's largest ever computational project, which will screen 3.5 billion molecules for cancer-fighting potential.[3]

This experience with 'distributed computational chemistry' was institutionally as well as technologically innovative. It moved scientific research far beyond the boundaries of the academic institution to involve equipment of the public in a leading-edge RCN. This was a major break from more conventional computational resources, such as built around a campus-based computing facility.

Nevertheless, this pioneering model was unique and certainly not a template for most of the OeSS case studies, nor UK e-Science projects generally. Across UK e-Science projects as a whole, most projects focused on creating tools, such as middleware, for distributed computing or tools linked to analysis of particular data sets, or other outputs, including software, data and publications (den Besten and David, 2009) within a particular institutional context. In most cases, the computational power needed for the Screensaver Project was not required of the social science and humanities projects. Large distributed networks and Grid computing networks were seldom built, as local computational resources were viewed as adequate. E-Science projects were generally innovative and successful, but varied primarily in the diversity of data that were the focus of research across many disciplinary domains, and the range of tools, such as open source software, developed for RCNs (Table 1).

However, from an institutional perspective, most were conducted within a single institutional setting or collaborative project, and not open to participation beyond the project, with the exception of access to results – as the distribution of research findings was one of the most active areas of innovation in open research. Exceptions were projects that created a collaborative Web 2.0 environment, such as MyExperiment, which enabled shared access to workflows for the scientific community (Table 1). However, even a number of notable innovations in open access, such as the substitution of a blog for physical lab notes in the CombeChem project, restricted access to the project team.

Reconfiguring access

The use of a growing range of RCNs could break the technological, geographical, institutional and disciplinary boundaries that might constrain research creativity and productivity. If implemented effectively, this could offer flexible and sustained support to enabling: increased participation, improved access and new ways to combine resources and skills. That would have an impact on shrinking or expanding psychological as well as physical distances among colleagues round the world, but not necessarily undermining the importance of geography. In fact, the opposite might well be the case. New technologies can also concentrate key resources to create new centres of worldwide expertise. These could lead to a concentration of related resources and knowhow, where geography could matter even more and inequalities in access to the tools of research could maintain and enhance local and global economic divides. This two-edged potential for technological change to open and close access is a common advance in technology generally.

All ICTs reshape access to information. In the context of scholarship, RCNs enable developers and users to reconfigure electronic and physical access to five distinct, but interrelated, resources central to research: reconfiguring access to expertise, observation, information, analysis and distribution, such as software, data or publications (Table 2).

Table 2 Reconfiguring access in research

Resource:	*Research-centred computational networks reconfigure:*
Expertise	How, where and when colleagues interact with co-authors, co-investigators, specialists and the public through all stages of research, reshaping collaboration networks.
Observation	The researcher's proximity to the object of study, whether a person or an object, bringing a researcher closer to an object of study, or enabling mediated observation, replacing or complementing more direct methods of observation.
Information	How and what researchers can collect, read, hear, see, archive – and know.
Analysis	How and from whom researchers obtain computational and data services; where and when they use in-house as opposed to external sources, and the capacity to process and visualize larger or more complex data sets.
Distribution	How and when researchers distribute information; what is distributed by whom; what is viewed by whom.

These are critical issues involving such questions as: Will researchers isolate themselves or increase collaboration with more widely distributed research teams, which potentially involve the citizen scientist? Will researchers be more distant from their objects of study, or closer to them? Will their observations be more direct, or more mediated? Will researchers collect more original data, or be more dependent on reuse of data collected by others? Will researchers design their analytical strategies or be more dependent on services provided by others (e.g. from within the academic sector or in a more proprietary Cloud)? How much of the data underlying research will be distributed? How open will research become and what will be the nature of such openness at different stages of the research process? In such ways, the choices made by developers and users of RCNs can reduce, reinforce or otherwise alter access, such as shaping information content and flow by accident or design. They can change the interactions between researchers, disciplines and organizations (Table 2).

Visualization is a useful example of reconfiguring access through new forms of analysis turned to visualizing research results. The value of visualizing data has been long recognized. Incentives for developing technologies to support this have been generated by efforts to enhance analytical capabilities not only for yielding insights for researchers – being able to see new patterns, but also to reach wider audiences, including other researchers, relevant policy makers and members of the public in clear and more engaging ways. The challenge is to combine the collection and analysis of high quality data sets with systems that can visualize the complex dynamics, such as social trends in the aging of populations, or global patterns of migration.

Moreover, many data sets can often be linked with geospatial information, such as social data that in turn can be linked with environmental or health indicators. In the natural sciences, Cornell University's Project eBird[4] project drew on amateur birdwatchers to provide information about what birds are spotted where and when, enabling the mapping of their movements. Initiatives to share and consolidate digital images of marine mammals (Table 1) enabled marine scientists to compile images taken by different researchers and better identify and track the movements of specific whales as well as other marine mammals across geographic distances and over time (Meyer, 2007).

In some respects, technological advances in RCNs broaden access to tools for visualization. For example, increasingly powerful analytical and visualization tools are available to household computer users through off-the-shelf software, such as tied to spreadsheets or statistical software, enabling most users to employ sophisticated approaches, much like advances in cameras enable amateur photographers to take more professional photos. In other respects, the centrality of visual analytics is fostering a burgeoning field of expertise, which uses techniques and guidelines for visual representations based on principles for reporting as well as the art of presentation to discover patterns within massive and dynamically changing information spaces. As the leading-edge of visual analytics continues to advance, institutions are pushed to bring in expertise to stay ahead of competing research centres.

However, some forms of visualization are becoming dependent on more distributed contributions from outside the academic institution and from a broader non-expert public of citizen scientists, as in the case of the eBird Project. Mapping the geography of crowdsourced information from the public can create new sources of scientific information that complement more traditional forms of data collection. In such ways, academic research institutions can be opened to participation by networked researchers, including 'citizen scientists', and in this sense opening and democratizing the research process, enabling users to co-create research.

Table 3 illustrates this focal issue in how RCNs might reconfigure access to research across each of the key resources of the research enterprise. On the one hand, RCNs can be used to maintain and reinforce the role of academic institutions, or to enable individual researchers within and outside of academic institutions to innovate from the bottom-up. The opening of research to empowering individual networked researchers could be a central issue in the politics of democratizing the next generation of IT-enabled academic research.

Networked institutions and networked researchers

One central way in which RCNs can shift communication and computational power in scholarly research is between what might be called 'networked institutions' *vs* 'networked researchers'. E-Research initiatives have focused on using advanced Internet and Grid technologies to support the role of existing research institutions, such as university computing facilities, and libraries. Super computer centres, campus Grids, institutional archives and repositories, and other major computing initiatives, such as digital libraries within universities, seek generally to maintain and enhance the role of the university and related institutions in providing informational, computational and networking resources for their users – students and staff, but primarily researchers (Table 3). Institutional actors think strategically about how they can employ RCNs to support their traditional roles as well as create new ways to extend the quality or scope of their activities.

However, the Internet and related RCNs do not only provide an opportunity to reinforce existing institutions. They enable the empowerment of what might be called 'networked individuals'[5] or 'networked researchers' vis-à-vis universities and other academic institutions (Dutton, 2007; Dutton and Eynon, 2009). In contrast to the thrust of institution-centric strategies, the growing use of the Internet and related RCNs are enabling networked researchers to reconfigure access to alternative sources of information, people and other resources. Such use enables networked researchers to move across, undermine and go beyond the boundaries of existing institutions.

An institutional focus has led to research giving too little attention to the practices and tools taken up by networked researchers, and an over-emphasis on institutional innovations, such as the 'institutional repository'. In academic institutions, many e-Research and related academic computing initiatives are reflected in similar developments outside of the institutional setting. Many universities are developing institutional repositories, but many academics deposit their working papers in open repositories, such as the Social

Table 3 Opening and democratizing research through RCNs

Resource	*Academic institutions*	*Networked researchers (NR)*	*Examples of innovations*
Expertise	Academic department, research centre, project team, collaboratory, Virtual Research Environment (VRE)	Distributed or collective intelligence, co-creation, citizen scientist, crowdsourcing of expertise	Collaborative software; galaxy zoo; eBird; Pynchon Literary Wiki
Observation	Expensive new equipment and instruments (e.g., telescopes, electron microscopes); large sensor networks	Inexpensive, shared or open source artifacts that enable a researcher to observe and collect information locally or worldwide	OpenNet initiative; Web-based survey software; public access to networked instruments (e.g. telescopes, microscopes), distributed intelligence
Information	Proprietary databases, data archives, grid-enabled data sets; large multi-media data sets	Webmetrics, online surveys, micro-expertise, crowdsourcing, open data	Use of the Internet, Web and search tools, Web crawlers, open linked data, such as Neurocommons
Analysis	University computing services, supercomputer centre, campus grid	Grid and Cloud services	Screensaver Project, searching of anti-cancer drugs, eBird, Pynchon Literary Wiki
Distribution	Institutional repositories	Open repositories, Science Wikis	Social Science Research Network (SSRN), MyExperiment
	Digital libraries	Digital collections	Distributed open Web of linked data
	Proprietary journals, books	Open access journals, science blogging and Web sites	CombeChem, JoVE, OpenWetWare

Science Research Network, or enable access to them via their own Web sites and blogs.

Similarly, the Access Grid (AG) is one major e-Research initiative in the UK, developed to support multi-node, multimedia conferencing among other forms of collaboration.[6] However, a small proportion of researchers around the UK and abroad have used AG technologies, which present many usability issues, while many have used more basic voice over Internet Protocol and other alternative technologies for audio and video conferencing (Meyer and Dutton, 2009). More generally, the use of e-Research tools has been very eclectic, driven by individual, bottom-up innovation, rather than following a top-down set of standard applications (Dutton and Meyer, 2009).

Researchers were also able to go to the Internet as well as their institution for support. By being well networked and able to go to the Internet for software, data and support, such as in relying on cloud services, they did not need to rely entirely on their university computer centre, or any particular e-Research initiative. In such ways, there is a more limited take-up of top-down RCN initiatives, while at the same time, the Internet and Web empower networked researchers as much as networked institutions.

A stark example is the Galaxy Zoo project, launched by an astronomy graduate student, Kevin Schawinski, and a post-doctoral researcher, Chris Lintott, at Oxford University. When Kevin Schawinski realized he could never collect the data he required for his classification of galaxies without the help of many volunteers, he and his colleagues designed software that enabled the general public to look at many pictures of galaxies to classify them, such as whether they are spiral or elliptical (Nielsen, 2011). The Web site[7] explains the research challenge quite simply:

> The Sloan Digital Sky Survey (SDSS) is taking images of a large portion of the sky and will eventually find a million galaxies. … . But out of these million galaxies, how do we know which are spirals and which are ellipticals? The answer is simple: look at them! … There are just too many galaxies for even the most dedicated of astronomers to look at. We need thousands of people to inspect galaxy images and to classify them as spiral or elliptical. We need you to help us.

With this request, a graduate student was able to use the Internet as an RCN to enhance his computational power to address an important scientific issue in a novel way and be more innovative than many academic research centres in seeing the potential for opening this project to a larger public – one that extended well beyond academia.

RCNs can reconfigure access in multiple ways, including their role in changing cost structures, expanding or contracting the proximity of access, restructuring the architecture of networks, creating and eliminating gatekeepers, redistributing advantages among different actors, or enabling more or less user control. All of these shifts in access could have implications for the quality of research.

Changing cost structures

RCN innovations can raise or lower the costs of accessing and distributing information and networked services. For instance, marginal costs of the online digital services and products are negligible, once a researcher has a broadband Internet link (e.g. in the preparation and publication of an academic paper).However, not every region, institution or researcher has such access, as in many developing counties.

Nevertheless, costs remain high in some contexts, such as producing, reviewing and promoting a major research database. Institutions, or nations, that are 'data rich' will have an advantage over those that are 'data poor' (Sawyer, 2008), such as is the case of the social sciences in China (Zhu and Li, 2010). At the same time, the free downloading of content (e.g. creative content like professional journal articles) has posed a serious challenge to cost structures for academic publishers. It has also encouraged researchers, universities and research councils to support the electronic distribution of papers, including supporting – even sometimes mandating – the development of institutional repositories.

Many widely available Internet-based services are of great value to researchers, such as search engines or cloud services, such as Google docs for distributed co-production of text. However, most academic institutions are unable to compete because of the huge development costs of commercial data centres, such as those built by major service providers (e.g. Google, Amazon.com, Yahoo! and Microsoft) that are anchored in substantial economies of scale. As a result, the cost to each user is very low, while it is very high to providers. A key impetus behind Grid computing has been this reduction in the number of major players across the world that have the capacity to compete with the major providers of computational services.

Expanding or contracting the proximity of access

RCNs can transform the structure, size, location and competitiveness of research activities by changing the ease, speed and costs of gaining access to people, services, information and technologies wherever they are located. The Internet and Grid enable researchers to keep in regular, informal touch with people in distant locations, and allow the delivery of files from around the world to desk, lab and laptop PC as easily as if they were stored on the researcher's own computer. Paradoxically, this ability to enable distributed collaboration across locations or to observe remote objects can lead to a distancing of researchers from one another, and from the objects of their study.

Restructuring the architecture of networks

The architecture of a technological network often reflects the social and institutional forces shaping it. Vertical communication structures, such as those used by traditional publishers and mass media, allow a small group to broadcast to millions, following a more centralized distribution of information. Likewise, research projects have traditionally often imposed a hierarchical management and communication structure, with organizational charts and reporting relationships being an essential element of major project proposals.

One of the basic features of the Internet and tools for collaboration, such as groupware, is its ease in supporting many forms of non-hierarchical structure, such as those based on horizontal 'peer networks' of communication (e.g. one-to-one, many-to-many). This distributed pattern of communication underpins much of the recent push for open access to science. It has also enabled individual researchers to choose whether or not to participate in emerging networks, which often span the formal boundaries of organizations (Dutton, 2008).

Creating and eliminating gatekeepers

Technological change can also alter the role of gatekeepers in the dissemination of information. Research Web sites, institutional archives, and a variety of electronic repositories enable the researcher to bypass journal editors, peer reviews, and even their own colleagues in getting research into the public domain. A clear example of this is the increasing use of science blogs by researchers to connect directly with their colleagues and other audiences.

Gatekeepers are relevant in communication beyond the publishing field. Secretaries were once the prime gatekeepers in research establishments, as elsewhere. Their screening and prioritizing of access to research teams (e.g. by answering telephone calls to an office) became less common as e-mail and social networking Web sites grew in popularity. Academics are increasingly in direct contact with students, the press (not the press office), their colleagues – and even strangers in the blogosphere – without the intervention of intermediaries.

Redistributing communicative and computational power

More generally, technological change in RCNs can reconfigure the 'communicative' and computational power of different actors. To paraphrase Nicholas Garnham (1999: 78), communicative power is a question of 'who commanded the cultural and material resources for communication', or in the case of RCNs, for networking and computation, and who is advantaged by this control.

Certainly, most innovations in RCNs are designed to enhance the power of researchers by enhancing their ability to access expertise, observe, get information, analyse data and disseminate research. But RCNs can redistribute communicative and computational power among researchers. For example, researchers that are cut out of networks are disadvantaged. Even those included in RCNs can be differentially advantaged. For example, there are a number of telescience centres that pool resources to create more powerful tools, such as the US National Aeronautics and Space Administration's orbiting Hubble telescope, which integrates advances in satellites, optics and computational science to enable scientists to see planets, stars and galaxies that would otherwise be invisible. As many of these images can be seen from anywhere in the world through the Internet, this enhances to computational and communicative power of even citizen scientists. However, not every astronomer has equivalent access to these resources. For example, some have earlier access, giving those able to support this shared resource an advantage over those who cannot.

User control over digital content and access

One particular shift in communicative and computational power could be towards the networked researcher *vs* the networked institution. Outside of academia, the Internet has democratized communication by opening access in ways that enable users to invent and reinvent tools and content (von Heppel, 2005). RCNs can also enable academics greater unfettered access to more sources of information and other research resources. For example, an increasing number of free, open source tools are available for researchers, but also to those who are not within academic institutions, enabling democratization or opening of research (Cardoso *et al*., 2010).

There are concerns about the loss of quality controls over academic, student and public access to scientific and research content. Conceptions of 'crowdsourcing' do not inspire the confidence of scientists, just as they frighten government officials and civil society. The elimination of the 'expert' gatekeeper has been made possible by the escalation of online communication channels. However, crowdsourcing is misleading as a term since most collaborative network organizations, from those co-creating Wikipedia to Galaxy Zoo, are well managed, moderated networks (Dutton, 2008).

In such ways, the advance of RCNs is enabling the opening of research, and creating opportunities for networked researchers to have more control over innovations in research methods and designs. However, there is a large ecology of actors shaping research policy and practice, and the role of RCNs.

An ecology of social and technological choices reshaping access

The reconfiguring access perspective provides a focus on how researchers can use the technologies like RCNs for countervailing purposes, such as whether to remain autonomous or to build distributed collaborative teams. All permutations of configurations are possible. However, no single actor in the research process is able to dictate outcomes. These are shaped by the interactions of multiple actors (such as computer scientists, domain scientists, research service organizations, business and industry, grant and funding agencies, professional associations) seeking to control and influence the design and use of RCNs, often pursuing different goals within their own domains (Dutton, 1992). Outcomes of choices unfold as the products of countless strategic and everyday decisions made by many actors, pursing different objectives in different social and institutional arenas.

The main factors affecting these digital choices are: economic, technological, social and ethical, geography, law and public policy, and institutional.

Economic resources and strategies

RCN initiatives owe much to major investments by governments in research infrastructures. Likewise, major constraints on the development and use of e-Research can arise from the size, wealth and vitality of different research communities, including universities and national and regional environments. The tools open to a prestigious American university department could dwarf those available in a distressed area of the global South. Economic resources are a constraint not only in developing regions. For example, proposed cuts in funding for astronomy in Britain, including cancellation of UK membership in the Gemini telescopic telescience tool, led to a major disruption in access to images from these internationally shared telescopic resources, which enabled UK astronomers to see the Northern Hemisphere through two of the best ranges of telescopes. Funding was eventually restored, but not before a number of UK academics left Britain to protect their academic careers (Pounds, 2007; Rincon, 2008).

Technological enablers and constraints

Technologies matter to the concept of reconfiguring access, which attaches much importance to the design of RCNs as platforms that make some activities easier or more rational to accomplish, and others more difficult. For example, the usability of RCNs can be a major constraint on up-take. The core e-Research vision is built around such notions as virtual collaboration, an arena that offers the means to shape choices about the potential pool of collaborative partners. Such visions have influence. For example, at a meeting of e-Social Science researchers, a proposal for a seminar series led some to imagine that the series would be held on the AG – a multipoint conferencing system, rather than at a single physical location. They had become embedded in a paradigm that took distributed virtual meetings for granted. It is in such ways, new technologies shape decisions about research practices and outcomes.

Cultural, social and ethical norms and practices

Ideas shaped by cultural, social, ethical norms and practices also matter in influencing choices about the use of RCNs. For instance, the underlying philosophy that shaped the emergence of the Internet from the 1970s was based on open access to information, communication and collaboration between people. However, approaches to e-Research can be shaped by the values, norms and practices of users, often anchored in disciplinary codes and practices and occur in very different ways from what would be expected by a simple extrapolation from the perceived potential of the technology (as in the 'impact' view of technologically enabled change). RCNs might enable the opening of research, but many research cultures remain skeptical of opening research to participants outside of a project, much less to the general public. How open or closed research is a key political issue that will be shaped in major ways by the culture of scientists, which has been a major force for opening or closing research, such as to citizen scientists (David *et al*., 2010; Nielsen, 2011).

Geography of space and place

One of the most prominent attributes of e-Research is the relative ease with which it can be used to overcome constraints of time and distance. Nevertheless, ICTs might actually bring new significance to locations, such as by enabling researchers to be where they need to be for face-to-face communication. Researchers can be in the field more often and at the most optimal times if they are able to rely on working remotely using effective network-enabled support. Alternatively, mediated research could be used instead of field research work. In such ways, RCNs also offer new choices about how to configure where different kinds of research are conducted.

Law and public policy

Public policy at all levels can constrain or promote research-centred computational. Many public policy initiatives have promoted RCNs, such as the Swiss Bio Grid, and the cyberinfrastructure initiative of the US National Science Foundation (2007). However, choices about access are constrained as well by a variety of laws and public policies, such as privacy and data protection. Privacy and data protection laws and policies vary, often dramatically, between jurisdictions (e.g. among the states of the European Union and across regions of the world). Rules related to copyright and IPR can facilitate or restrict access to material in any form. Research administrators are developing approaches that can clarify and address these issues. However, such cross-jurisdictional differences can pose a potential barrier to the free flow of information in many research domains, such as in the social and medial sciences. The experience of researchers associated with the eDiaMoND grid project, pooling and distributing digital mammogram images ran into a number of issues over ownership of the images, and the privacy of patient records, that had not been fully anticipated in early design phases (Jirotka *et al.*, 2005).

Institutional and disciplinary regulations, codes and practices

Digital choices in universities and other research establishments are affected by institutional arrangements and policies in areas such as IPR, copyright and liability, such as the contractual difficulties that often beset multi-institutional collaborations (David and Spence, 2010). Powerful norms and practices in academia can stem also from disciplinary codes. Most disciplines socialize their students by instilling norms, such as how to protect personal data, when to keep what confidential, how to maintain records, and how and when to publish their work. Even mandates from public authorities can be ignored by researchers who believe they violate their disciplinary codes of practice, as in a social scientist protecting the anonymity of the participants in their research.

In contrast to technologically deterministic perspectives on the nature and impacts of e-Research, the social choices shaping RCNs are more often the unpredictable outcome of an ecology of choices across a multiplicity of actors. As a consequence, many social scientists who have attempted to identify the practical implications of RCNs on research are critical of overly simplistic perspectives on predicted 'impacts' (e.g. Hine, 2006; Borgman, 2007; Olson *et al.*, 2008). The thrust of the more conventional impact perspective focuses on the potential contribution of well-implemented technological innovations to particular patterns of use and outcome, suggesting that predicted benefits will progress with an inherent logic after the successful adoption of a new technology. In e-Research, which would point to the use of RCNs, leading inevitably to better connected researchers across institutional and national boundaries, with wider access to information resources. This would be seen as flowing from the great and growing capacities brought by the Grid and global footprint of the Web.

This traditional impact perspective has dominated discussion of technology and society from its emergence in studies of computers in the 1950s. However, empirical research routinely finds that this thesis can be misleading because it ignores the degree to which the outcomes of these innovations can lead to a diversity of impacts (Dutton, 1996, 1999). For example, the same technologies could be used in ways that isolate or connect researchers by enabling an individual to work either independently or in a collaborative team. More articles are becoming accessible online, but that does not mean that researchers are relying on more sources. In fact, over time, proportionately fewer sources are being cited by authors (Evans, 2008). This uncertainty creates an important role for information scientists in clarifying the multiplicity of requirements behind the design of effective RCNs.

Summary and conclusion

RCNs have been the focus of computer scientists and domain scientists within a relatively small but growing community of academics focused on e-Research across the disciplines. It is therefore not surprising that these developments have been led by a technologically deterministic logic of funding the top-down development of new infrastructures for research institutions, which have met with much success as well as disappointment. However, this area has also been the site of some dramatic innovations in research, which have illustrated the potential for innovations led by networked researchers to reconfigure access to the research enterprise, often opening research beyond the confines of traditional academic institutions.

The diffusion of these innovations is constrained by a wide variety of factors, highlighted in this synthesis of our case studies of e-Research. Given the cultural, institutional, legal and disciplinary factors shaping the design and uptake of innovative approaches to research, it is necessary to accept a long-term perspective that does not focus on the next few years but on the coming decades (Nielsen, 2011). Despite this pace of change, the significance of these new infrastructures for research is great. The Internet took 40 years to move from a promising innovation to an accepted part of everyday life and work. A similar time horizon is required for RCNs.

This article has focused on how the design and use of RCNs enable the reconfiguration of access to the objects of study, the colleagues one works with, the analytical tools of research and the audiences being targeted. Choices aimed at reconfiguring access are constrained by an ecology of choices by multiple actors, each with different objectives – but constrained by a variety of factors outlined above. This interaction of social and technological choices over time and across domains produces unpredictable outcomes, but they can be better anticipated if the design and development of RCNs is informed by study of the full ecology of choices and not overly focused on the technological.

The major theme that emerged from this synthesis was the potential for RCNs to open up all phases of research, not simply the distribution of findings and other outputs of research. Those scholars and administrators who understand the centrality of the ways in which RCNs can be used to reconfigure access to local and global research resources could be in a better position to decide whether, and how, to use the technologies.

It is clear that choices are geared to supporting existing institutions of scholarly research, such as universities and libraries, but that some of the most innovative and transformative choices have been made by networked researchers, who have exploited the potential of the Internet and related RCNs to empower themselves and open up opportunities to engage participants in collaborative networks that would have been unimaginable in earlier eras. In short, networked researchers are likely to have a major influence on what approaches are developed and used. Whether or not this leads to better quality research outcomes depends on the choices made by individuals and groups about how to design and use (or not use) RCNs to reconfigure access strategically in ways that open up or close off networks of collaboration, calculation and communication.

No single researcher or research team can be master of their own fate. They operate in the context of multiple players within complex institutional settings that might not adapt to changing research practices. Therefore the success of e-Research will depend on a widespread understanding of the nature of changing practices and their outcomes, as well as on the strategic choices of individual actors. Law, policy, institutional and disciplinary contexts must adapt – not just individual scholars. RCNs cannot autonomously overturn entrenched and deeply rooted legal norms, institutional arrangements, or cultural influences, particularly since researchers most often use technologies to reinforce their existing practices. Nevertheless, shifts in the research power of various actors enabled by the technology could open up possibilities for significant transformations in many traditional ways of conducting research, with far reaching consequences on its outcomes.

The future is not simply a technological choice but also a political choice. It is not simply a dichotomy between empowering individual researchers by opening opportunities for users to be a key source of innovation in research, or focusing on maintaining and enhancing the communicative and computational power of academic institutions. Nevertheless, the quality of research will be shaped by the politics of the next generation of research infrastructures, what I have called Research-centred Computation Networks. The ecology of choices that will shape this future should be informed by scholars of information technology with an understanding of these dynamics, and not simply left to domain scientists or computer scientists within a strong but still nascent e-Research community.

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Notes

1 Details about OeSS are available at: http://microsites.oii.ox.ac.uk/oess/.

2 More detailed discussion of individual case studies are provided on the project Web site at: http://microsites.oii.ox.ac.uk/oess/.

3 http://www.chem.ox.ac.uk/curecancer.html.

4 http://ebird.org/content/ebird/about.

5 The notion of networked individuals corresponds to the term 'networked individualism' used by Barry Wellman (2001) to break old dichotomies between the individual and place-based communities. I have developed and extended this concept in my work on the Fifth Estate (Dutton, 2007).

6 See: http://www.accessgrid.org/.

7 http://zoo1.galaxyzoo.org/Project.aspx.

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